mine subsidence ENGINEERING CONSULTANTS

South32

Illawarra Metallurgical Coal

SOUTH32 ILLAWARRA METALLURGICAL COAL:

Dendrobium - Area 3B - Longwall 15

End of Panel Subsidence Monitoring Review Report for Dendrobium Longwall 15

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft Issue	JB	PD	01 May 20
A	Final Issue	JB	PD	13 May 20

Report produced for: Compliance with conditions attached to the SMP Approval set by Industry and Investment NSW (now DPIE).

Associated reports:

WKA77 (January 2001) – Dendrobium Mine Project – Report on the prediction of mining subsidence parameters and the assessment of impacts on surface infrastructure – Longwalls 1 to 18 (in support of the EIS).

MSEC311 (October 2007) – The prediction of subsidence parameters and the assessment of mine subsidence impacts on natural features and surface infrastructure resulting from the extraction of proposed Longwalls 6 to 10 in Area 3A and future longwalls in Areas 3B and 3C at Dendrobium Mine (in support of the SMP Application and the Modification to the Development Consent).

MSEC459 (September 2012) – Dendrobium Area 3B – Longwalls 9 to 18 – subsidence predictions and impact assessments for natural features and surface infrastructure in support of the SMP Application.

MSEC792 (December 2015) – Dendrobium Area 3B – Longwalls 12 to 18 – Review of the subsidence predictions and impact assessments for natural and built features in Dendrobium Area 3B based on observed movements and impacts during Longwalls 9 and 10.

MSEC865 (November 2016) – The effects of the proposed modifications to the ends of Longwalls 12 to 18 in Area 3B at Dendrobium Mine on the subsidence predictions and impact assessments.

MSEC914 (August 2017) – The effects of the proposed modified commencing ends of Longwalls 15 to 18 in Area 3B at Dendrobium Mine on the subsidence predictions and impact assessments.

Background reports available at *www.minesubsidence.com*:

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

CONTENTS

LIST OF TABLES, FIGURES AND DRAWINGS

Tables

Tables are prefixed by the number of the section in which they are presented.

Figures

Figures are prefixed by the number of the section in which they are presented.

Drawings

Drawings referred to in this report are included in Appendix A at the end of this report.

Drawing No.	*Description*	*Revision*
MSEC1101-01	General layout and monitoring lines	A
MSEC1101-02	Natural features	A
MSEC1101-03	Built features	A
MSEC1101-04	Measured incremental horizontal movement vectors due to LW15	A

1.1. Introduction

Illawarra Metallurgical Coal (IMC) has completed the extraction of Longwall 15 (LW15) at Dendrobium Mine, which is in the Southern Coalfield of New South Wales. The locations of the longwalls in Area 3B at Dendrobium Mine are shown in Drawing No. MSEC1101-01, in Appendix A. The extraction of LW15 commenced on the 9 April 2019 and it was completed on the 22 January 2020.

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IMC to prepare subsidence predictions and impact assessments for Dendrobium Longwalls 9 to 18 (LW9 to LW18) in Area 3B. Report No. MSEC459 (Revision B) was issued in September 2012 in support of the SMP Application for these longwalls.

IMC then shortened the finishing (i.e. eastern) end of LW15 by 254 m and shortened the commencing (i.e. western) end by 86 m from the extents that were indicated in the SMP Application. The maximum height of extraction in the Wongawilli Seam for LW15 to LW18 was also reduced from 4.6 m to 3.9 m. Reports Nos. MSEC865 (Rev. A) and MSEC914 (Rev. A) were issued in support of the applications for these modifications. The Subsidence Management Plan for LW15 was approved by the Department of Planning and Environment on the 16 December 2016.

The subsidence prediction model was reviewed and re-calibrated, based on the updated monitoring data from LW7 and LW8 in Area 3A and LW9 and LW10 in Area 3B. The subsidence predictions and impact assessments for the natural and built features were reviewed and updated based on the re-calibrated subsidence model and are provided in Report No. MSEC792 (Rev. C). The predictions provided in this End of Panel subsidence review report are based on the re-calibrated subsidence prediction model outlined in Reports Nos. MSEC792 and MSEC865.

In accordance with Condition 9 End of Panel Reporting of the Development Consent (Schedule 3) for the Area 3B longwalls, this report provides:

- comparisons between the measured and predicted subsidence effects at the monitoring lines and points in Dendrobium Area 3B resulting from the extraction of LW15; and
- comparisons between the observed and predicted effects and impacts on the natural and built features within the SMP Area resulting from the extraction of LW15.

Further details on the observed and assessed impacts for natural features, resulting from the extraction of LW15, are provided in the reports by other consultants. The discussions provided in this report should be read in conjunction with those and all other relevant reports.

Chapter 2 of this report describes the locations of the ground monitoring lines and points which were surveyed during the extraction of LW15. This section also provides comparisons between the measured and predicted effects resulting from the extraction of this longwall.

Chapter 3 of this report describes the natural and built features near LW15. This section also provides comparisons between the observed and assessed impacts for these features resulting from the extraction of this longwall. Further discussions on the observed and assessed impacts for natural features are provided in reports by other consultants.

Chapter 4 of this report provides a summary of the comparisons between the measured and predicted ground movements and the observed and assessed surface impacts due to the extraction of LW15.

Appendix A includes all drawings associated with this report.

1.2. Mining geometry

The layout of the longwalls in Area 3B at Dendrobium Mine is shown in Drawing No. MSEC1101-01, in Appendix A. A summary of the as-extracted dimensions for LW9 to LW15 is provided in Table 1.1.

Table 1.1 Mining geometry of the as-extracted longwalls

Location	Longwall	Overall void length including installation heading (m)	Overall void width including first workings (m)	Overall tailgate chain pillar width (m)
Area 3B	LW9	2162	305	-
	LW10	2219	305	45
	LW11	2204	305	45
	LW12	2602	305	45
	LW13	2223	305	45
	LW14	1980	305	45
	LW15	1963	305	45

The mined lengths of the longwalls excluding the installation headings are approximately 9 m shorter than the overall void lengths provided in Table 1.1. The length of extraction for LW15, therefore, is approximately 1954 m. The longwall face widths excluding the first workings are approximately 294 m.

The longwalls in Area 3B have been extracted from the Wongawilli Seam, from the west towards the east, i.e. towards Wongawilli Creek. The natural surface and the seam levels along the centreline of LW15 are illustrated in Fig. 1.1.

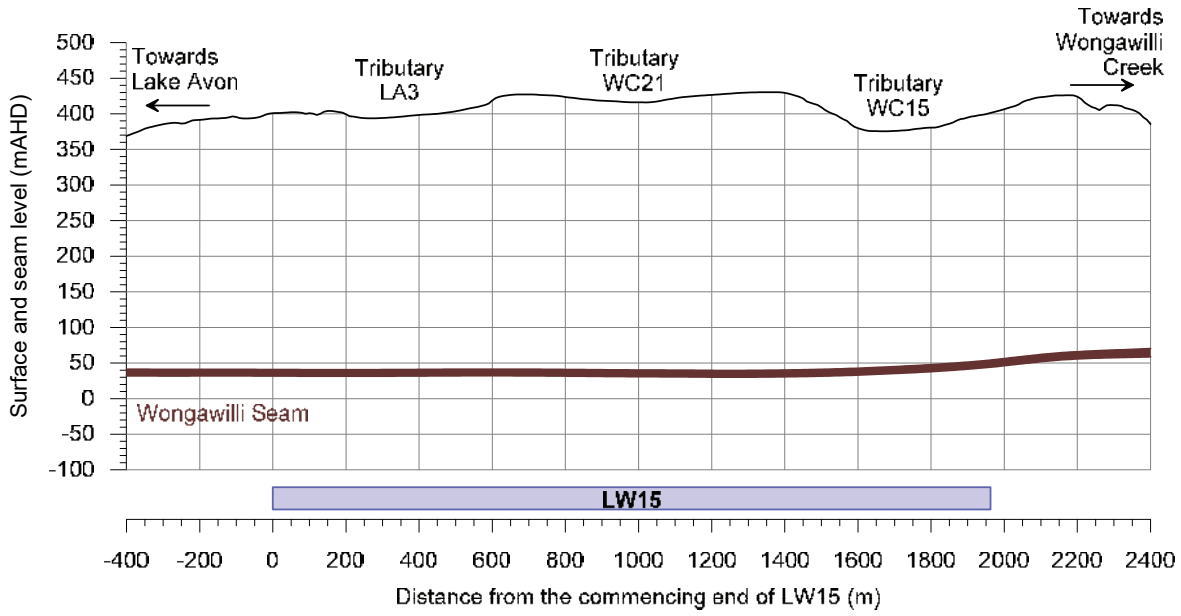


Fig. 1.1 Surface and seam levels along the centreline of LW15

The depth of cover to the Wongawilli Seam, directly above LW15, varies between a minimum of 330 m near the commencing (i.e. western) and finishing (i.e. eastern) ends of the longwall, and a maximum of 395 m near the middle of the longwall. The seam floor within the mining area generally dips from the south to the north, having an average dip around 2 %, or 1 in 50.

The extraction height varies along the length of LW15, depending on the local roof conditions, with a maximum mining height of 3.9 m. The predictions provided in this report have been based on the maximum proposed extraction height of 3.9 m, as adopted in Reports Nos. MSEC459, MSEC792 and MSEC865.

2.1. Introduction

The mine subsidence movements resulting from the extraction of Dendrobium LW15 were monitored along several monitoring lines and monitoring points including the following:

- Wongawilli Creek closure lines;
- Avon Dam closure lines;
- Area 3B and Avon Dam 3D monitoring points;
- WC15 and WC21 cross lines;
- Swamp cross lines; and
- Airborne laser scans of the area.

The locations of these survey lines and survey points are shown in Drawing No. MSEC1101-01, in Appendix A. Comparisons between the measured and predicted subsidence effects at these monitoring lines and points are provided in the following sections. The predicted subsidence parameters have been obtained using the re-calibrated subsidence model presented in Reports Nos. MSEC792 and MSEC865.

2.2. Wongawilli Creek closure lines

The closure movements across Wongawilli Creek have been measured by IMC using 2D survey techniques at the Wong X B-Line, Wong X C-Line, Wong X D-Line and Wong X E-Line. The Wong X A-Line was not measured at the completion of LW12 to LW15 due to its distance north-east of these longwalls.

The locations of the Wongawilli Creek closure lines are shown in Drawing No. MSEC1101-01. The survey dates for these monitoring lines are provided in Table 2.1.

Table 2.1 Survey dates for the Wongawilli Creek closure lines for LW15

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Completion of LW15	13 February 2013 (base survey) 4 March 2016 (end of LW11) 28 April 2017 (end of LW12) 14 June 2018 (end of LW13) 28 March 2019 (end of LW14) 28 March 2020 (end of LW15)	Completion of each of the future longwalls in Area 3B

The monitoring lines each comprise two survey marks, with the marks located on either side of Wongawilli Creek and, therefore, they measure closure between the valley sides. Survey marks could not be located near the base of the valley due to the difficult terrain. The upsidence in the base of the valley, therefore, could not be measured.

The development of total closure for the Wongawilli Creek closure lines, due to the extraction of LW6 to LW15, is illustrated in Fig. 2.1. The base survey for the Wong X D-Line was carried out after the completion of LW12 and, therefore, this line measured the additional movements due to LW13 to LW15 only. The base survey for the Wong X E-Line was carried out after the completion of LW14 and, therefore, this line measured the additional movements due to LW15 only.

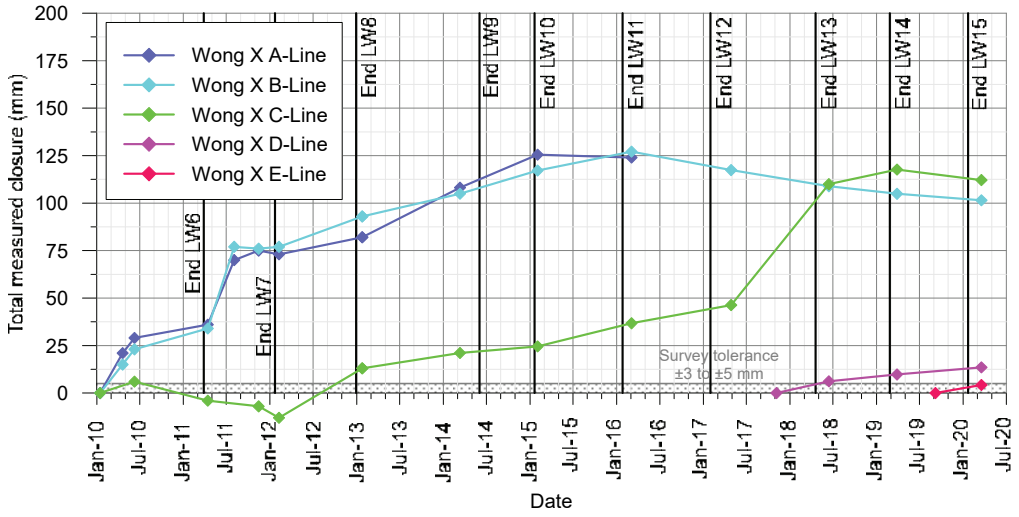


Fig. 2.1 Development of total closure for the Wongawilli Creek closure lines

There were slight reductions in the total closures measured at the Wong X B-Line and Wong X C-Line and slight increases in the total closures measured at the Wong X D-Line and Wong X E-Line due to the mining of LW15.

The predictions of vertical subsidence, upsidence and closure for Wongawilli Creek, resulting from the mining of Dendrobium LW6 to LW19, were provided in Report No. MSEC865. The measured and predicted total closures along Wongawilli Creek after the completion of LW15 are illustrated in Fig. 2.2.

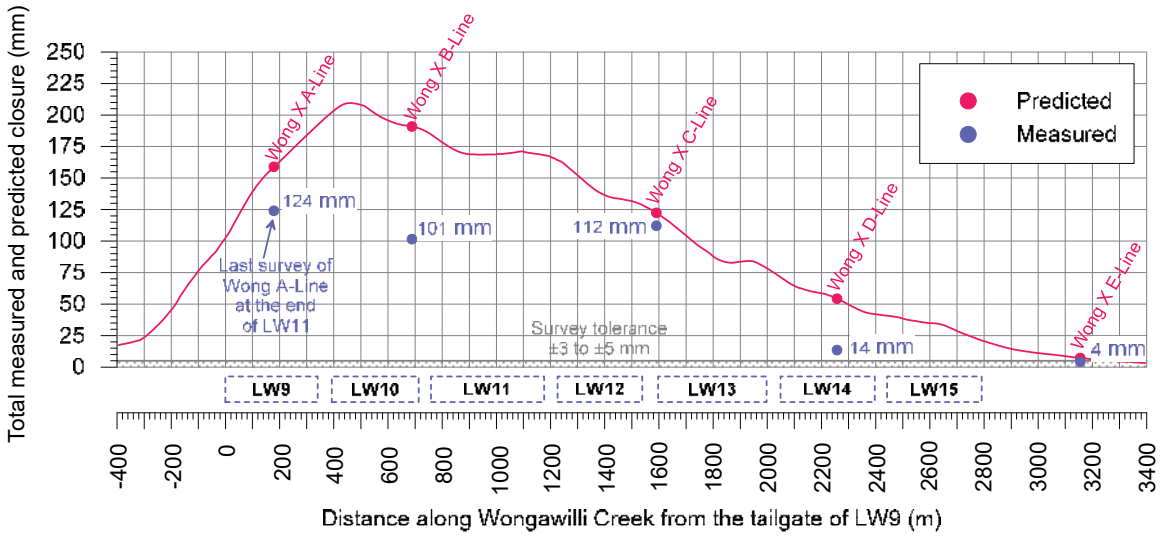


Fig. 2.2 Measured and predicted total closure along Wongawilli Creek after LW15

A summary of the maximum measured and maximum predicted total closure movements for each of the Wongawilli Creek closure lines, due to the extraction of LW6 to LW15, is provided in Table 2.2. The predicted total closures consider the shortened finishing ends of LW11, LW12, LW14 and LW15.

Table 2.2 Measured and predicted total closure at the Wongawilli Creek closure lines due to the extraction of LW6 to LW15

Location	Longwalls	Measured total closure (mm)	Predicted total closure (mm)
Wong X A-Line	LW6 to LW11	124	160
Wong X B-Line	LW6 to LW15	101	190
Wong X C-Line	LW6 to LW15	112	120
Wong X D-Line	LW13 to LW15	14	50
Wong X E-Line	LW15 only	4	10

The accuracies of the measured closure movements are in the order of ±5 mm.

The maximum measured total closures at each of the Wongawilli Creek closure lines are similar to or less than the predicted values at the completion of LW15. It is considered that the movements measured using the Wongawilli Creek closure lines are reasonably consistent with the predictions provided in Reports Nos. MSEC792 and MSEC865.

2.3. Avon Dam closure lines

The closure across the Avon Dam has been measured by IMC using the Avon Dam A-Line to E-Line. The locations of these monitoring lines are shown in Drawing No. MSEC1101-01. The discussions on the Avon Dam 3D monitoring points are included in Section 2.4.

The survey dates for the Avon Dam closure lines are provided in Table 2.3. The base surveys were carried out just prior to the commencement of LW12 and, therefore, the closure lines have measured the accumulated movements due to the extraction of LW12 to LW15 only.

Table 2.3 Survey dates for the Avon Dam closure lines during LW15

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Completion of LW15	12 February 2016 (base survey) 30 August 2016 (end of LW12) 23 May 2018 (end of LW13) 2 April 2019 (end of LW14) 28 May 2019 20 August 2019 1 November 2019 5 February 2020 (end of LW15)	Completion of each of the future longwalls in Area 3B

The monitoring lines each comprise two survey marks, with the marks located on either side of the Avon Dam and, therefore, they measure closure between the valley sides. Survey marks could not be located near the base of the valley due to the stored water in the dam. The upsidence in the base of the valley, therefore, could not be measured.

The development of the measured accumulated closures across the Avon Dam closure lines during the extraction of LW12 to LW15 are illustrated in Fig. 2.3. The extraction of LW15 has resulted in a small decrease in the closure measured at the A-Line and small increases in the openings measured at each of the other monitoring lines.

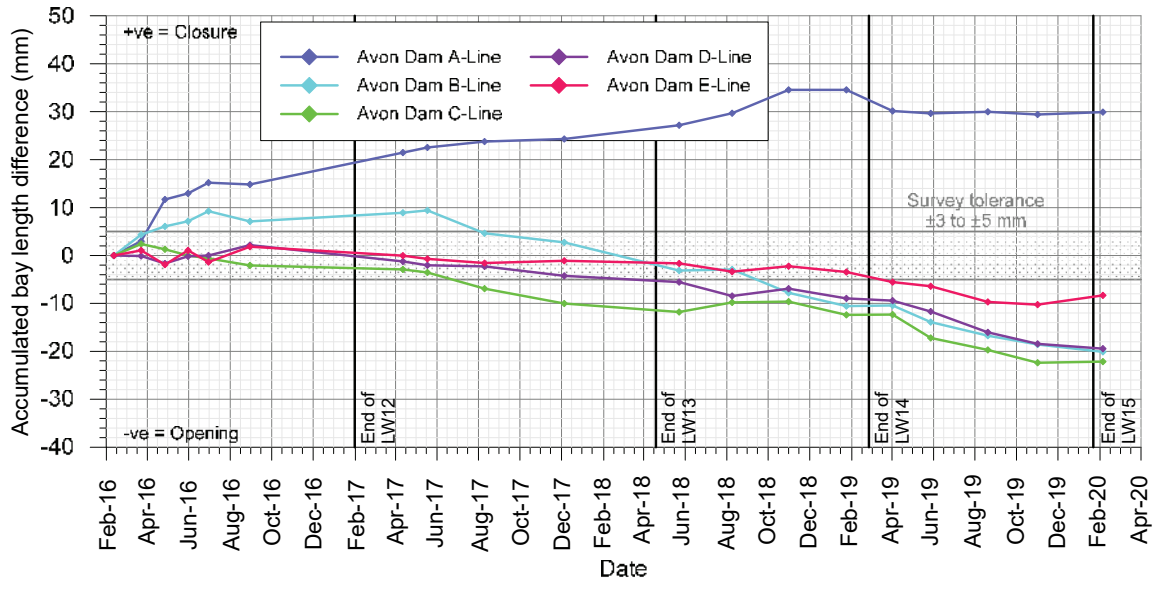


Fig. 2.3 Measured and predicted accumulated closure for the Avon Dam closure lines

A summary of the maximum measured and maximum predicted accumulated movements for each of the Avon Dam closure lines, due to the extraction of LW12 to LW15, is provided in Table 2.2. The predicted closures due to the earlier extracted LW9 to LW11 are negligible, i.e. less than 20 mm. The measured values are based on the latest survey dated 5 February 2020.

Table 2.4 Maximum measured and maximum predicted accumulated movements for the Avon Dam closure lines due to the extraction of LW12 to LW15

Location	Measured accumulated closure (mm)	Predicted accumulated closure (mm)
Avon Dam A-Line	30	70
Avon Dam B-Line	-20 (opening)	80
Avon Dam C-Line	-22 (opening)	70
Avon Dam D-Line	-19 (opening)	< 20
Avon Dam E-Line	-8 (opening)	< 20

The accuracies of the measured closure movements are in the order of ±5 mm.

The maximum measured total movements at the Avon Dam closure lines are less than the predicted values at the completion of LW15. It is considered that the ground movements measured using these monitoring lines are consistent with the predictions provided in Reports Nos. MSEC792 and MSEC865.

The closure across Avon Dam and two tributaries to the dam (Refs. LA4A and LA4B) have also been measured by IMC using the Avon Dam GPS (Marks Den3B-05A, Den3B-06 and Den3B-07). The base survey was carried out on the 26 February 2013, i.e. prior to the commencement of LW9. Subsequent surveys were carried out on the same dates as the Avon Dam closure lines, as summarised in Table 2.3.

The development of the measured accumulated closures across LA4A (Den3B-06 to Den3B-07), LA4B (Den3B-05A to Den3B-06) and the Avon Dam (Den3B-05A to Den3B-07) during the extraction of LW12 to LW15 are illustrated in Fig. 2.4.

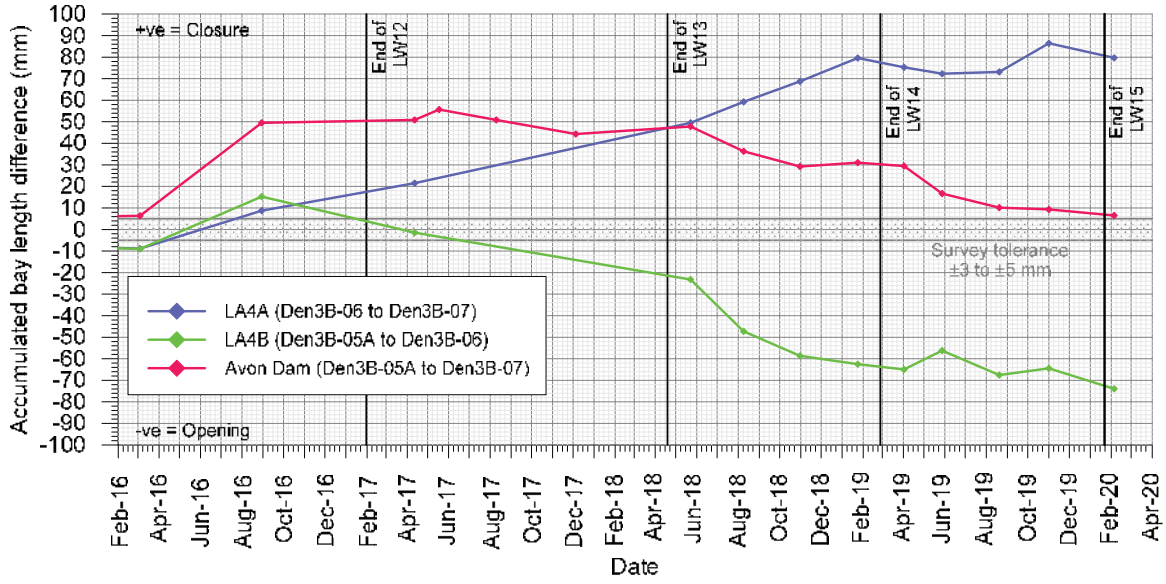


Fig. 2.4 Measured accumulated closure for Tributaries LA4A and LA4B and the Avon Dam

A summary of the total measured and total predicted closures across LA4A, LA4B and Avon Dam is provided in Table 2.5. The measured closure is less than the predicted final closure at the completion of LW15. The vertical subsidence was not measured using these monitoring lines.

Table 2.5 Maximum measured and predicted total closure across LA4A, LA4B and the Avon Dam due to the extraction of LW9 to LW15

Location	Measured accumulated closure (mm)	Predicted accumulated closure (mm)
LA4A (Den3B-06 to Den3B-07)	80	170
LA4B (Den3B-05A to Den3B-06)	-74 (opening)	170
Avon (Den3B-05A to Den3B-07)	7	80

The accuracies of the measured closure movements are in the order of ±5 mm.

The maximum measured total closure movements across the LA4A and the Avon Dam monitoring lines are less than the predicted values at the completion of LW15. Opening was measured across the LA4B monitoring line as the far-field horizontal movement of Mark Den3B-06, towards the longwall mining area, was greater than the valley closure effects across the tributary to Lake Avon. The net movement measured across the LA4B monitoring line is dependent on the positions of the two survey marks on the valley sides.

The ground movements measured using these monitoring lines are considerably less than the predictions provided in Reports Nos. MSEC792 and MSEC865.

2.4. Dendrobium Area 3B 3D and the Avon Dam 3D monitoring points

The far-field horizontal movements near LW15 have been measured by IMC using the Dendrobium Area 3B 3D monitoring points (DA3B 3D) and the Avon Dam 3D monitoring points. The locations of these monitoring points are shown in Drawing No. MSEC1101-01.

The survey dates for the DA3B 3D monitoring points for LW15 are provided in Table 2.6. The survey dates and monitoring commitments for the Avon Dam 3D monitoring points are the same as the Avon Dam closure lines provided in Table 2.3.

Table 2.6 Survey dates for the DA3B 3D monitoring points for LW15

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Completion of LW15	26 February 2013 (base survey) 4 March 2016 (end of LW11) 9 March 2017 (end of LW12) 15 May 2018 (end of LW13) 23 April 2019 (end of LW14) 24 April 2020 (end of LW15)	Completion of each of the future longwalls in Area 3B

The measured incremental horizontal movement vectors for DA3B 3D and the Avon Dam 3D monitoring points, due to the extraction of LW15, are shown in Drawing No. MSEC1101-04. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of ±20 mm.

The vectors of incremental horizontal movement are typically orientated towards LW15 and skewed towards the east, i.e. towards the longwall finishing end, or in the downslope direction. The greatest movements have been measured directly above LW15 and, to lesser extents, above the previously extracted LW14. Only low level incremental horizontal movements have been measured outside the extents of the mining area.

The comparison between the maximum measured incremental horizontal movements at the DA3B 3D and Avon Dam 3D monitoring points with those previously measured in Dendrobium Area 1 (DA1 3D) and Dendrobium Area 2 (DA2 3D), Dendrobium Area 3A (DA3A 3D), as well as other collieries in the Southern Coalfield, is provided in Fig. 2.5. The mean and the 95 % confidence level for the 3D monitoring data at Dendrobium Mine are also shown in this figure.

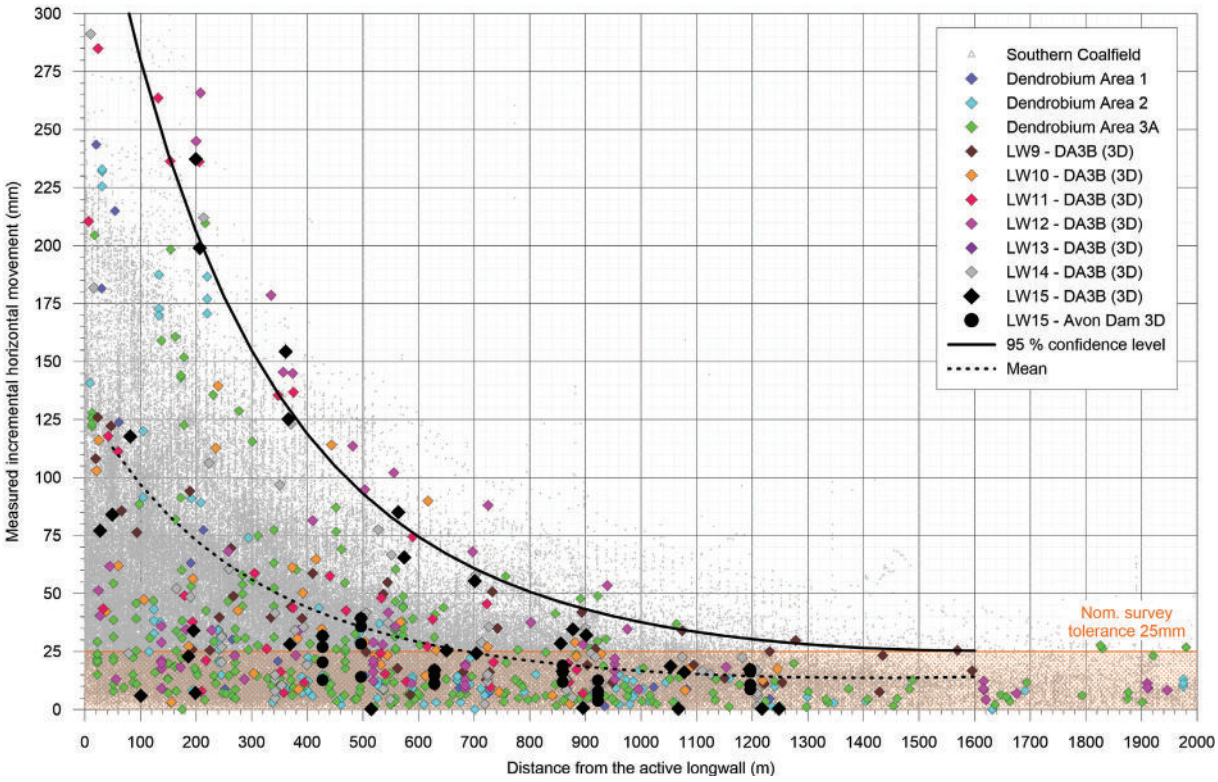


Fig. 2.5 Measured incremental horizontal movements at Dendrobium Mine

The measured incremental horizontal movements resulting from the extraction of LW15 (i.e. black diamonds and circles) are typically within the range of those measured at similar distances from previously extracted longwalls at Dendrobium Mine (i.e. blue, cyan, green, brown, orange, red, magenta, purple and grey diamonds) and elsewhere in the Southern Coalfield (i.e. grey triangles).

2.5. WC15 cross lines

The mine subsidence movements across WC15 (a tributary to Wongawilli Creek) have been measured by IMC using 2D survey techniques using the WC15 RB9-Line, WC15 RB28-Line and WC15 RB34-Line. These monitoring lines were established in December 2018 during the mining of LW14.

The locations of the WC15 cross lines are shown in Drawing No. MSEC1101-01. The survey dates for these monitoring lines for LW15 are provided in Table 2.7.

Table 2.7 Survey dates for the WC15 cross lines for LW15

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Monthly once the longwall face is nominally 100 m before the cross line until it is 400 m past	13 December 2018 (base survey) 15 January 2019 15 February 2019 28 March 2019 (end of LW14) 23 July 2019 17 October 2019 17 December 2019 21 January 2020 18 March 2020 (end of LW15)	Monthly once the longwall face is nominally 100 m before the cross line until it is 400 m past

The development of the measured accumulated closures at the WC15 cross lines are illustrated in Fig. 2.6. The monitoring lines were established during the mining of LW14 and, therefore, they do not include the effects of LW9 to LW13. These monitoring lines have short lengths and located near the valley base and, therefore, they may not measure the maximum closure within the valley.

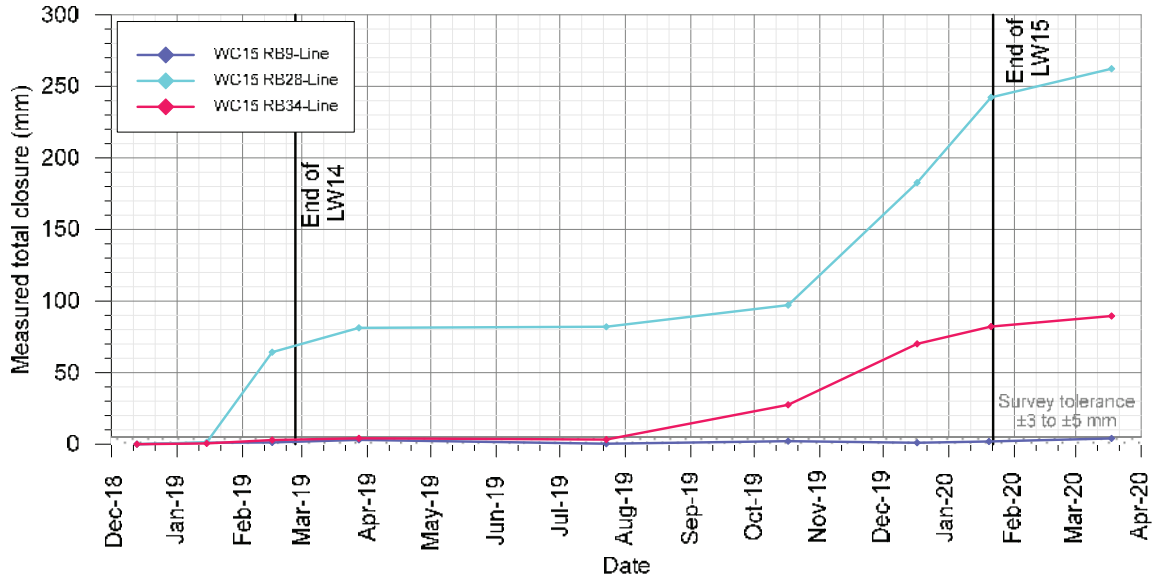


Fig. 2.6 Measured accumulated closure for the WC15 cross lines due to LW14 and LW15

Summaries of the maximum measured and predicted accumulated subsidence and closure at the WC15 closure lines, due to the extraction of LW14 and LW15, are provided in Table 2.8 to Table 2.10. The predicted subsidence values have been derived from the predicted subsidence contours illustrated in Report No. MSEC865. The predicted closures are based on a combination of the conventional horizontal movements and valley related movements, taking the equivalent heights of the valleys within half-depths of cover from the valley bases.

Table 2.8 Maximum measured and predicted accumulated subsidence and closure at the WC15 RB9-Line resulting from the extraction of LW14 and LW15

Type	Maximum accumulated subsidence (mm)	Maximum accumulated closure (mm)
Measured	-19 (Uplift)	4
Predicted	< ±20	270

Table 2.9 Maximum measured and predicted accumulated subsidence and closure at the WC15 RB28-Line resulting from the extraction of LW14 and LW15

Type	Maximum accumulated subsidence (mm)	Maximum accumulated closure (mm)
Measured	89	262
Predicted	400	260

Table 2.10 Maximum measured and predicted incremental subsidence and closure at the WC15 RB34-Line resulting from the extraction of LW14 and LW15

Type	Maximum accumulated subsidence (mm)	Maximum accumulated closure (mm)
Measured	-17 (Uplift)	90
Predicted	< ±20	240

The accuracies of the measured absolute levels of the survey marks are in the order of ±30 mm. The accuracies of the measured closures are in the order of ±5 mm.

The subsidence measured at WC15 RB28-Line of 89 mm is less than the predicted value of 400 mm. Low level net uplift were measured at WC15 RB9-Line and WC15 RB34-Line, which are in the order of the survey tolerance for absolute height.

The closure measured at the WC15 RB28-Line of 262 mm is similar to but slightly greater than the predicted value of 260 mm. The exceedance of 2 mm (i.e. 0.7 %) is less than the accuracy of the prediction method for valley closure effects. The closures measured at the WC15 RB9-Line and WC15 RB34-Line are less than their predicted values.

The ground movements measured using WC15 cross lines are similar to or less than the predictions provided in Reports Nos. MSEC792 and MSEC865.

2.6. WC21 cross lines

The mine subsidence movements across WC21 (a tributary to Wongawilli Creek) have been measured by IMC using 2D survey techniques using the WC21 J-Line, WC21 K-Line, WC21 L-Line (lower) and WC21 L-Line (upper). The remaining WC21 cross lines were not measured during LW15.

The locations of the WC21 cross lines are shown in Drawing No. MSEC1101-01. The survey dates for these monitoring lines for LW15 are provided in Table 2.11.

Table 2.11 Survey dates for the WC21 cross lines for LW15

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
First survey 100 m before lines, then monthly surveys. Final survey when mining 400 m past lines	13 February 2013 (base survey) 4 March 2016 (end of LW11) 28 April 2017 (end of LW12) 14 June 2018 (end of LW13) 28 March 2019 (end of LW14) 23 July 2019 21 August 2019 25 September 2019 17 October 2019 18 March 2020 (end of LW15)	First survey 100 m before lines, then monthly surveys. Final survey when mining 400 m past lines

The development of the measured total closures at the WC21 cross lines are illustrated in Fig. 2.7. The WC21 J-Line, K-Line, L-Line (lower) and L-Line (upper) were established on the 5 October 2016 and, therefore, they do not include the effects of LW9 to LW11. These monitoring lines have short lengths and located near the valley base and, therefore, they may not measure the maximum closure within the valley.

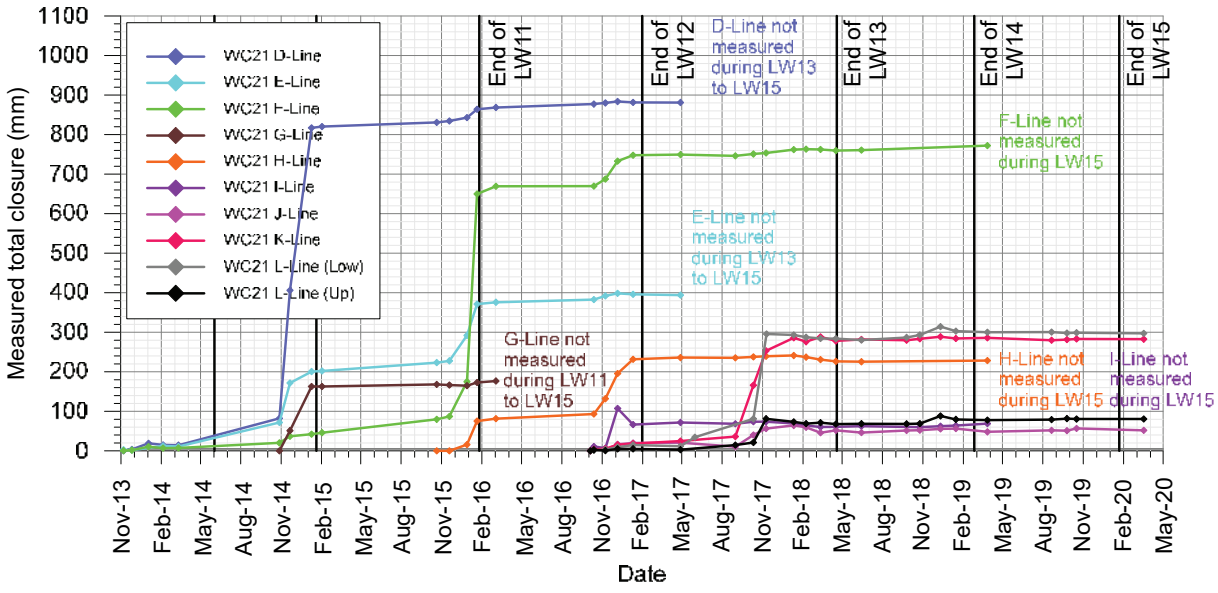


Fig. 2.7 Measured total closure for the WC21 cross lines

There were small changes in the total closures measured at the WC21 cross lines due to the extraction of LW15. These monitoring lines are located at distances ranging between 500 m and 730 m north of LW15, above the previously extracted longwalls.

Summaries of the maximum measured and predicted total subsidence and closure at the WC21 cross lines, after the completion of LW15, are provided in Table 2.12 to Table 2.14. The predicted subsidence values have been derived from the predicted subsidence contours illustrated in Report No. MSEC865. The predicted closures are based on a combination of the conventional horizontal movements and valley related movements, taking the equivalent heights of the valleys within half-depths of cover from the valley bases.

Table 2.12 Maximum measured and predicted total subsidence and closure at the WC21 J-Line resulting from the extraction of LW12 to LW15

Type	Maximum total subsidence (mm)	Maximum total closure (mm)
Measured	886	52
Predicted	1400	310

Table 2.13 Maximum measured and predicted total subsidence and closure at the WC21 K-Line resulting from the extraction of LW12 to LW15

Type	Maximum total subsidence (mm)	Maximum total closure (mm)
Measured	1289	282
Predicted	2225	720

Table 2.14 Maximum measured and predicted total subsidence and closure at the WC21 L-Line (lower and upper) resulting from the extraction of LW12 to LW15

Type	Maximum total subsidence (mm)	Maximum total closure (mm)
Measured	1996	297
Predicted	3100	720

The accuracies of the measured absolute levels of the survey marks are in the order of ±30 mm. The accuracies of the measured closures are in the order of ±5 mm.

The measured total vertical subsidence and closure for the WC21 cross lines are less than the predicted values at the completion of LW15. The measured vertical subsidence movements range between 58 % and 64 % of the predicted values, with an average of 62 %. The measured closures range between 17 % and 41 % of the predicted values, with an average of 32 %.

The ground movements measured using WC21 cross lines are considerably less than the predictions provided in Reports Nos. MSEC792 and MSEC865.

2.7. Swamp cross lines

The mine subsidence movements across the swamps and their associated drainage lines have been measured by IMC using 2D survey techniques using the SW11-Line, SW13-Line and SW23-Line. The remaining swamp cross lines were not measured during LW15.

The locations of the swamp cross lines are shown in Drawing No. MSEC1101-01. The survey dates for these monitoring lines are provided in Table 2.15.

Table 2.15 Survey dates for the swamp cross lines during LW15

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
First survey 100 m before lines then monthly surveys, final survey when mining 400 m past lines	9 February 2015 (base survey) 17 February 2016 (end of LW11) 28 February 2017 (end of LW12) 15 May 2018 (end of LW13) 26 March 2019 (end of LW14) 7 May 2019 (SW11 and SW23) 12 June 2019 (SW11 and SW23) 21 August 2019 (SW13 only) 25 September 2019 (SW13 only) 25 October 2019 (SW13 only) 18 January 2020 (end of LW15)	First survey 100 m before lines then monthly surveys, final survey when mining 400 m past lines

Summaries of the maximum measured and predicted total subsidence and closure along the swamp cross lines, resulting from the extraction of LW11 to LW15, are provided in Table 2.16 to Table 2.18. The base survey for the SW23-Line was carried out after the completion of LW13 and, therefore, the results for this monitoring line are due to LW14 and LW15 only.

The measured values for SW11-Line, SW13-Line and SW23-Line are based on the latest survey dated 18 March 2020. The predicted subsidence values have been derived from the predicted subsidence contours illustrated in Report No. MSEC865. The predicted closures are based on a combination of the conventional horizontal movements and valley related movements, taking the equivalent heights within half-depths of cover from the valley bases.

Table 2.16 Maximum measured and predicted total subsidence and closure at the SW11-Line resulting from the extraction of LW11 to LW15

Type	Maximum total subsidence (mm)	Maximum total closure (mm)
Measured	*Not measured*	-17 (opening)
Predicted	250	180

Table 2.17 Maximum measured and predicted total subsidence and closure at the SW13-Line resulting from the extraction of LW11 to LW15

Type	Maximum total subsidence (mm)	Maximum total closure (mm)
Measured	1516	42
Predicted	2050	330

Table 2.18 Maximum measured and predicted total subsidence and closure at the SW23-Line resulting from the extraction of LW14 and LW15

Type	Maximum total subsidence (mm)	Maximum total closure (mm)
Measured	*Not measured*	8
Predicted	< 20	110

The accuracies of the measured absolute levels of the survey marks are in the order of ±30 mm. The accuracies of the measured closures are in the order of ±5 mm.

The maximum measured total vertical subsidence and closure at the SW11-Line, SW13-Line and SW23-Line are all less than the predicted values. The measured vertical subsidence at the SW13-Line is 74 % of the predicted value. Opening was measured along the SW11-Line. The measured closures at the SW13-Line and SW23-Line are 13 % and 7 %, respectively, of the predicted values. It is noted that marks have been disturbed along each of the monitoring lines and, therefore, the actual closures could be greater than those measured. In any case, it is expected that the actual closure for these monitoring lines would be considerably less than the predicted values.

The ground movements measured using Swamp cross lines are considerably less than the predictions provided in Reports Nos. MSEC792 and MSEC865.

2.8. ALS / LiDAR surveys

The changes in surface level due to the extraction of LW9 to LW15 have been measured using Airbourne Laser Scan (ALS) / Light Detection and Ranging (LiDAR) surveys. The initial surface level contours have been determined from the base survey carried out in January 2013, prior to the extraction of LW9. The post mining surface level contours have been determined from the subsequent surveys carried out in February 2014 after LW9, in January 2015 after LW10, in April 2016 after LW11, in March 2017 after LW12, in May 2018 after LW13, in March 2019 after LW14 and in February 2020 after LW15.

The measured incremental changes in surface level due to the extraction of LW15 only are shown in Fig. 2.8. These contours have been determined by taking the differences between the surface levels measured before and after the extraction of this longwall. The data located outside the predicted limit of vertical subsidence (i.e. incremental 20 mm subsidence contour) have been removed for clarity.

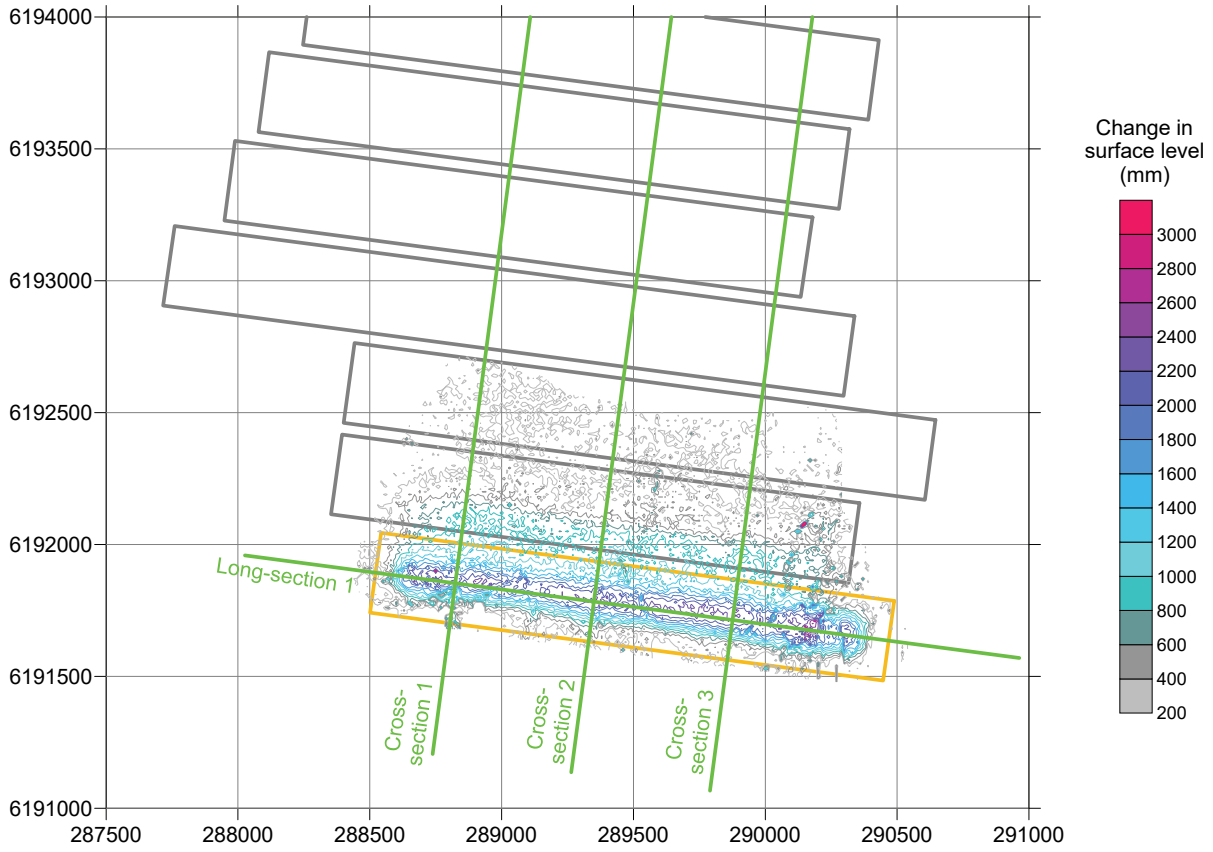


Fig. 2.8 Measured incremental changes in surface level due to the extraction LW15

The measured total changes in surface level due to the extraction of LW9 to LW15 are shown in Fig. 2.9. These contours have been determined by taking the differences between the surface levels measured before the extraction of LW9 and after the completion of LW15. The data located outside the predicted limit of vertical subsidence (i.e. total 20 mm subsidence contour) have been removed for clarity.

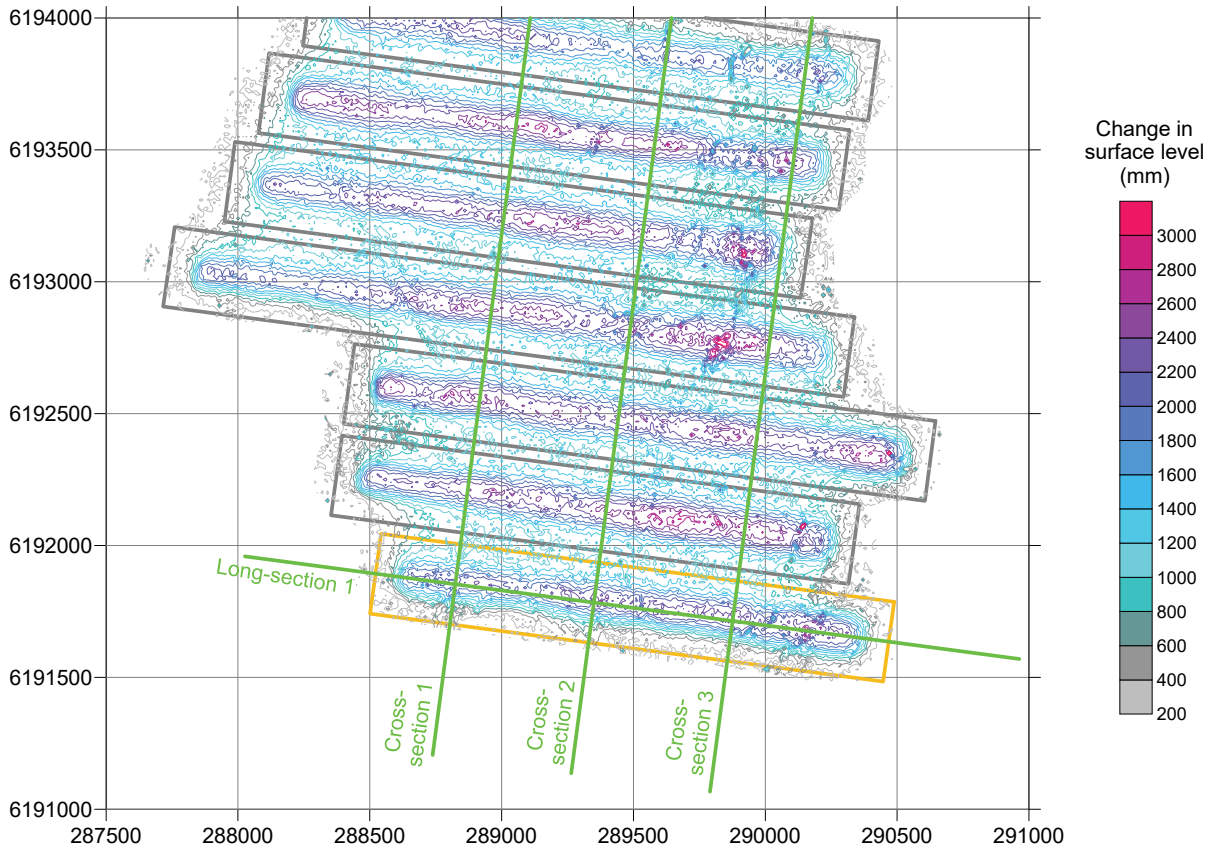


Fig. 2.9 Measured total changes in surface level due to the extraction of LW9 to LW15

The LiDAR surveys have an accuracy for absolute level in the order of ±100 mm. The accuracy of the measured changes in surface level (i.e. the difference between two surveys), therefore, is in the order of ±200 mm.

The contours of the measured changes in surface level, developed from the LiDAR surveys, show the changes in the heights of points at fixed positions in space (i.e. eastings and northings). This differs from traditional subsidence contours that include both the vertical and horizontal components of the movements of points fixed to the surface. Horizontal movements are usually included in the subsidence profiles, as traditional ground monitoring data is based on the movements of survey marks that are fixed to the ground.

The contours can contain artefacts (i.e. locally increased or decreased movements), particularly in the locations of steeply incised terrain, such as at the cliffs and steep slopes. These artefacts can be seen in Fig. 2.8 and Fig. 2.9 as the localised areas of dark purple to red contours above the longwalls and the lower level subsidence outside the extents of the longwalls.

The change in surface level at a fixed position in space (i.e. easting and northing), therefore, can be large in the locations of cliffs and steep slopes and does not provide a true indication of the actual vertical subsidence at a point on the ground. However, where the ground is reasonably flat, the contours of the measured changes in surface level should provide a good indication of the actual vertical subsidence.

The comparisons of the measured changes in surface level and the predicted vertical subsidence along Cross-sections 1 to 3 and Long-section 1 are provided in Fig. 2.10 to Fig. 2.13. The locations of these sections are indicated in Fig. 2.8 and Fig. 2.9. The predicted profiles of vertical subsidence have been derived from the predicted subsidence contours illustrated in Report No. MSEC865.

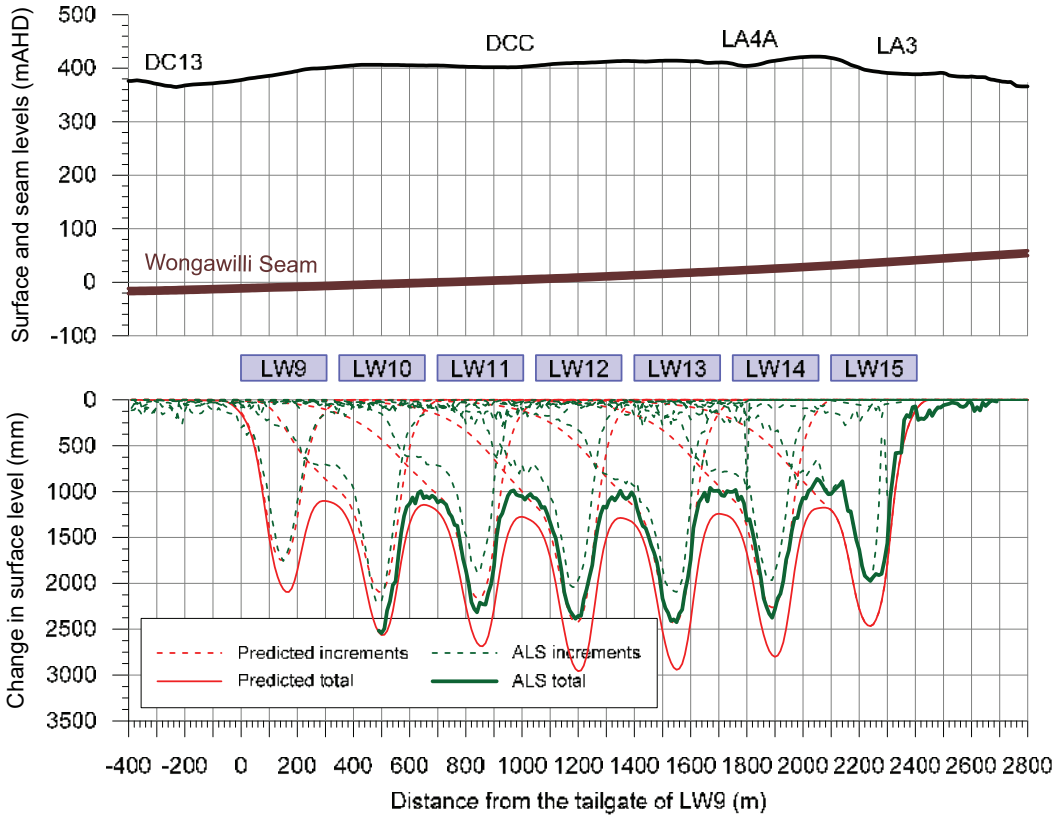


Fig. 2.10 Measured changes in surface level and predicted vertical subsidence along Cross-section 1

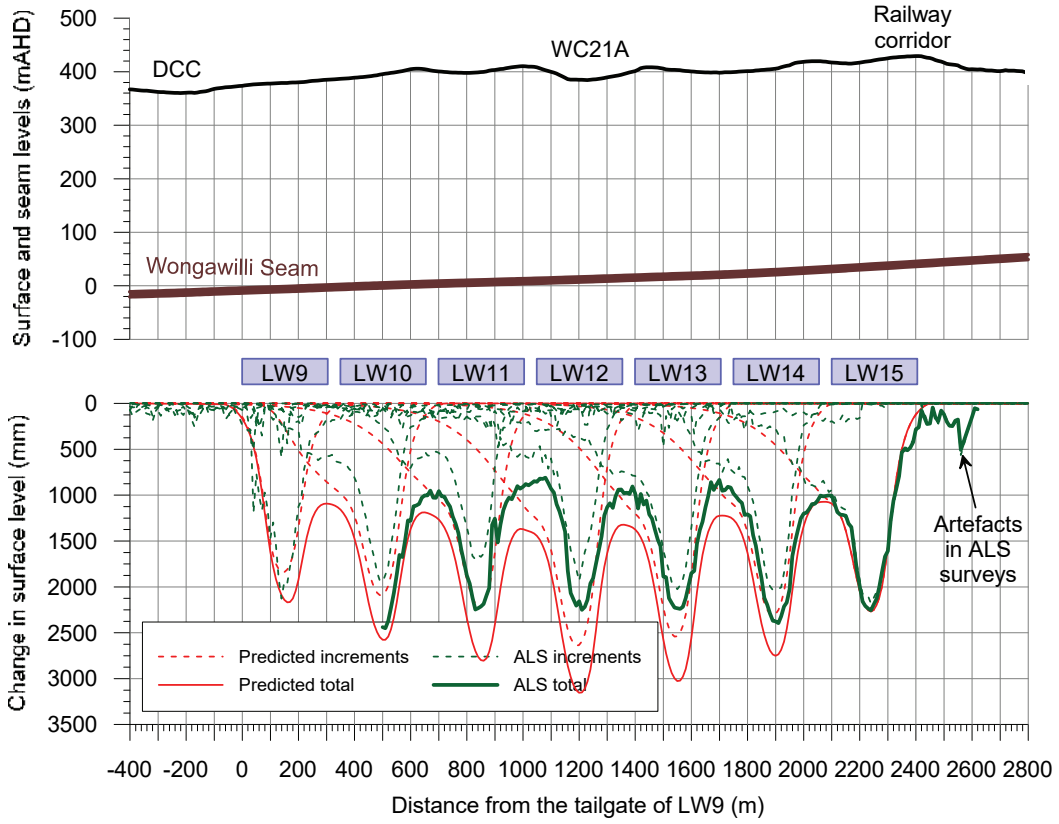


Fig. 2.11 Measured changes in surface level and predicted vertical subsidence along Cross-section 2

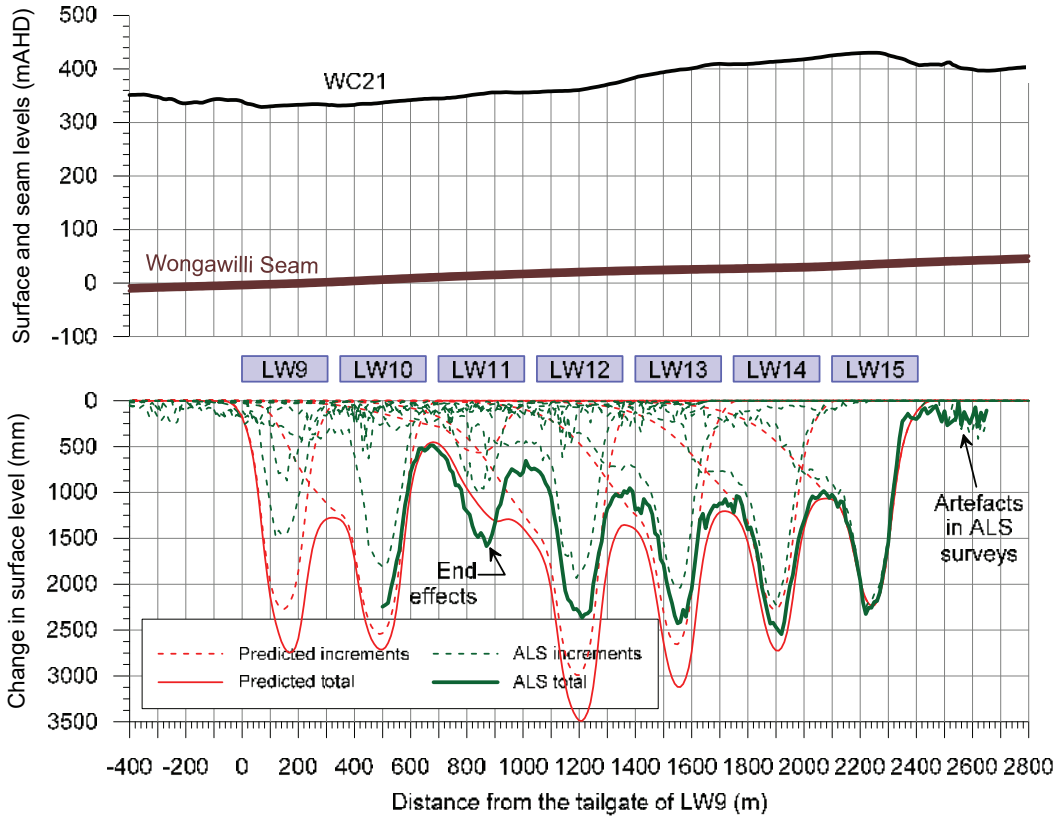


Fig. 2.12 Measured changes in surface level and predicted vertical subsidence along Cross-section 3

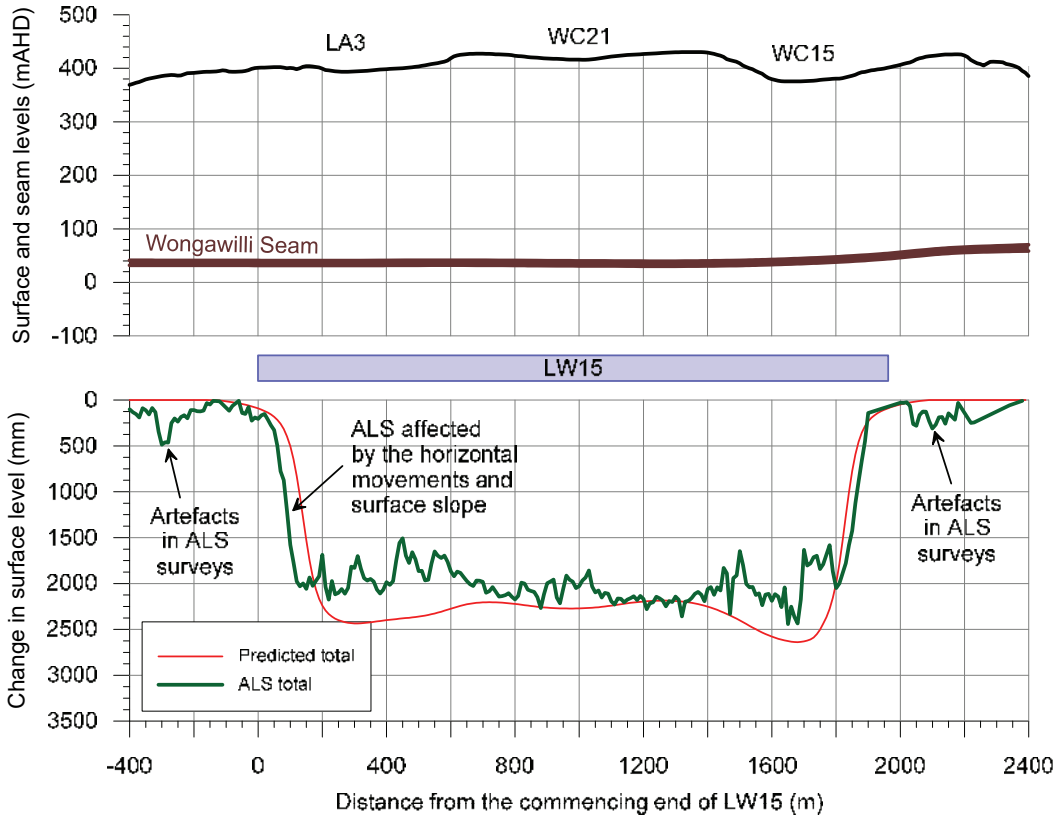


Fig. 2.13 Measured changes in surface level and predicted vertical subsidence along Long-section 1

The profiles of the measured changes in surface level reasonably match the predicted profiles of vertical subsidence along each of the cross-sections and long-section. The maximum measured changes in surface level above each of the longwalls are similar to or less than the maximum predicted values. Also, the measured changes in surface level above each of the chain pillars are similar to or less than the predicted values in these locations.

The measured change in surface level along Cross-section 3 (refer to Fig. 2.12) is slightly greater than the predicted vertical subsidence above LW11. This cross-section is located close to the finishing end of LW11 and, therefore, the predictions are influenced by the longwall end effects. The difference between the measured and predicted movements are in the order of accuracy of the measurement method.

The measured change in surface level along Long-section 1 (refer to Fig. 2.13) is greater than the predicted vertical subsidence above the commencing end of LW15 (i.e. left side of figure). However, this may be partly due to the surveying tolerance and the effects of the horizontal movements and sloping terrain on the LiDAR surveys. The ground directly above the commencing end of LW15 has moved towards the longwall (i.e. following the extraction face) as illustrated in the horizontal movement vectors in Drawing No. MSEC1101-04. The natural surface dips towards the west in this location (i.e. towards Lake Avon). The mining-induced horizontal movement, therefore, results in the measured changes in level at a fixed position to be greater than the true vertical subsidence above the commencing end of LW15.

There are localised areas outside of the longwalls where the measured changes in surface level exceed the predicted vertical subsidence. However, these are artefacts of the LiDAR surveys and are not real movements.

It can be inferred from the slopes of the profiles, that the measured changes in grade are similar to the predicted tilts along each of the cross-sections and long-section. It is not possible to derive the curvature nor the horizontal movements from the LiDAR surveys.

It is considered that the ground movements measured using the LiDAR surveys are consistent with the predictions provided in Reports Nos. MSEC792 and MSEC865.

3.1. Surface deformations

The surface deformations due to the extraction of LW15 have been identified by the IMC Environmental Field Team and are described in the accompanying IMC landscape report. The locations of the soil cracking and rock fracturing identified during the extraction of LW15 are illustrated in Fig. 3.1.

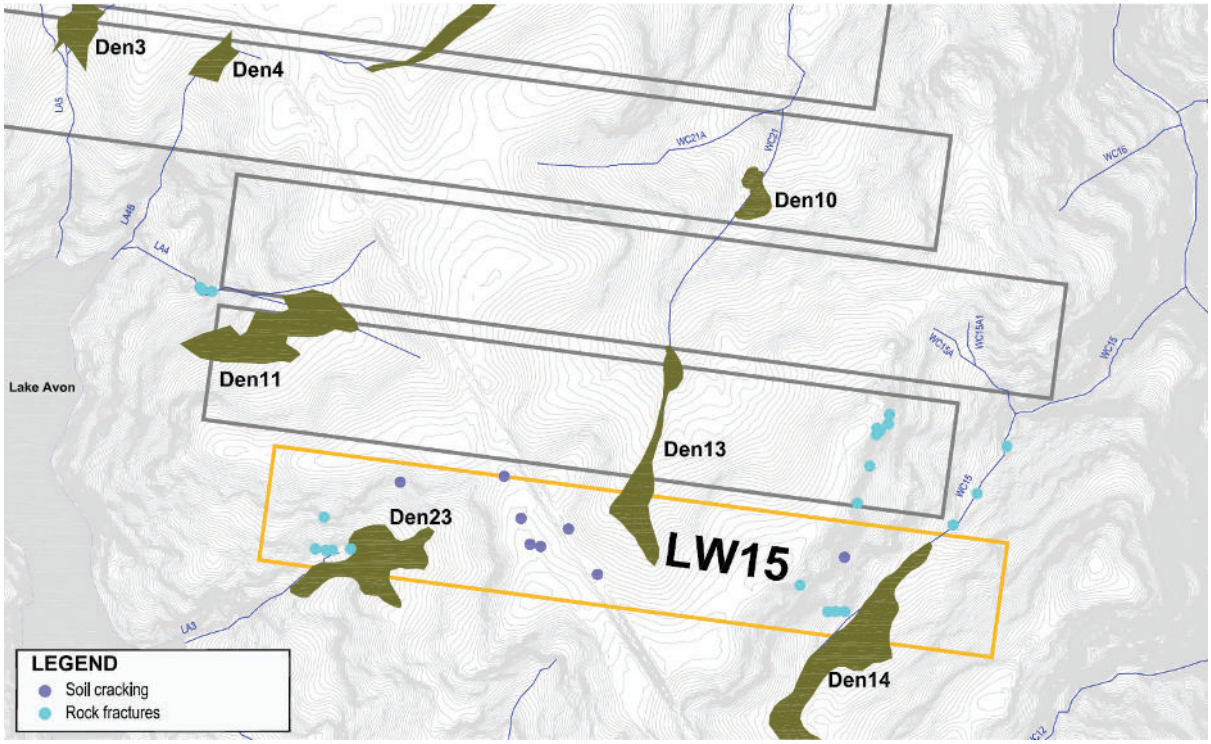


Fig. 3.1 Surface deformations due to the extraction of LW15

Soil cracking (i.e. blue circles) was identified directly above LW15 at 8 sites located along or near the fire trails, seismic tracks, railway corridor and bases of steep slopes. Rock fracturing (i.e. cyan circles) was also identified at 11 sites located along the ridgeline above the eastern ends of LW14 and LW15 and at 5 sites located within the valley of LA3 to the west of Swamp Den23. The maximum measured crack and fracture widths range between 2 mm and 80 mm.

Rock fracturing was identified at three sites along WC15 due to the mining of LW15. There are additional sites along the tributary with fracturing identified after LW13 (8 sites) and after LW14 (8 sites). A summary of the sites along WC15 with fracturing attributed to the mining of LW15 is provided in Table 3.1. The locations of these sites are also illustrated in Fig. 3.2.

Table 3.1 Fracturing sites observed along WC15 attributed to the mining of LW15

Site ID	Location	Longwall when fracturing was first observed	Maximum fracture width (mm)	Surface water flow diversion
DA3B_LW13_035	Rockbar 21	LW14	20	Surface water flow diversion observed after LW14
DA3B_LW14_016	Rockbar 25	LW14	30	Not observed but possible under higher surface water flows
DA3B_LW15_027	Rockbar 18	LW15	40	Fracture not located in direct surface water flow path

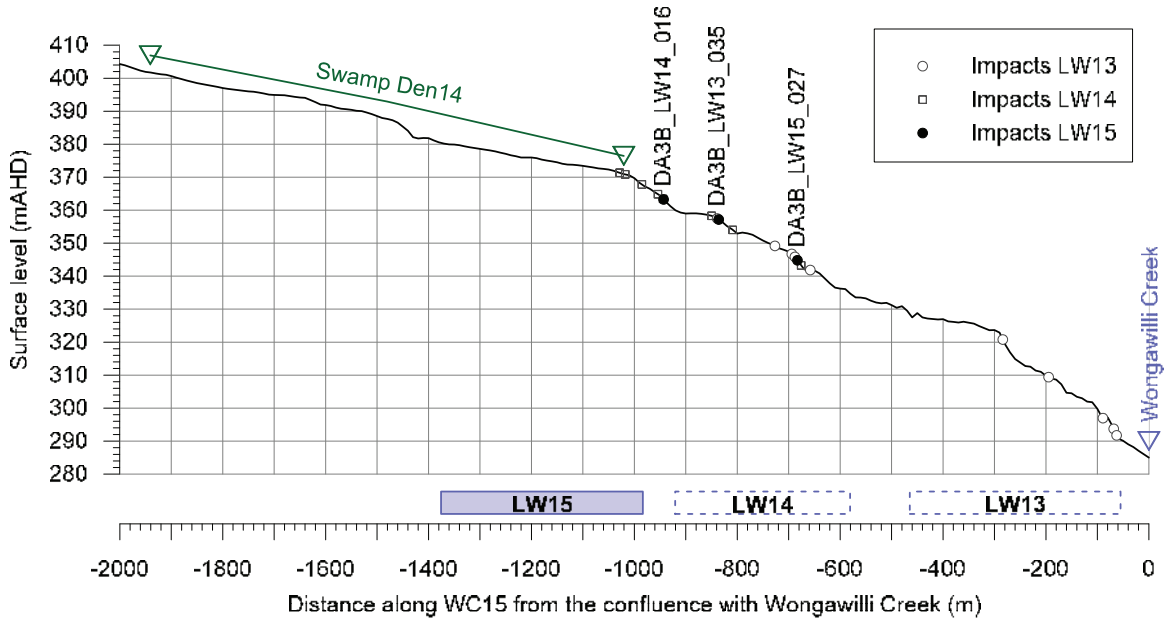


Fig. 3.2 Rock fractures identified along WC15

Rock fracturing was also identified at three sites along LA4A after the mining of LW15. It is likely that these impacts occurred during the mining of LW14 and that they only later became visible due to rainfall events which dislodged vegetation and rock fragments. The maximum measured fracture widths range between 2 mm and 20 mm. No surface water diversions were observed at these sites during the site inspections; however, diversions are possible under higher surface water flows.

Further details of these surface deformations are provided in the accompanying IMC landscape report.

3.2. Natural features

The natural features near Dendrobium LW15 are shown in Drawing No. MSEC1101-02, in Appendix A, and include:

- Wongawilli Creek;
- Donalds Castle Creek;
- drainage lines;
- cliffs;
- rock outcrops;
- steep slopes;
- swamps; and
- archaeological sites.

The MSEC assessed impacts for the natural features resulting from the extraction of Dendrobium LW9 to LW18 are provided in Report No. MSEC459, which supported the SMP Application. These assessments were reviewed and updated based on the re-calibrated subsidence model and are provided in Reports Nos. MSEC792 and MSEC865. More detailed assessments for the natural features were also provided in other consultants' reports.

Comparisons between the MSEC assessments and the reported impacts for the natural features listed above, resulting from the extraction of LW15, are provided in Table 3.2. The reported impacts are based on those recorded by IMC Environmental Field Team that are described in the accompanying landscape report.

Table 3.2 Assessed and reported impacts for the natural features due to LW15

Natural feature	MSEC assessed impacts	Reported impacts
Wongawilli Creek	Very localised additional **ponding** or **flooding** developing in the locations of existing pools, steps or cascades due to vertical subsidence or tilt.	No reported impacts due to the mining-induced vertical subsidence or tilt.
	Minor **fracturing** of the bedrock within 400 m of the longwalls due to strain.	No new fracturing identified along the creek due to the mining of LW15. Fracturing was previously observed between LW6 and LW9, first observed during the mining of LW9.
	Low-likelihood that **surface water flow diversions** would occur due to fracturing of the bedrock.	No new surface water flow diversions (i.e. Type 3 impacts) identified along the creek due to the mining of LW15. One Type 3 impact was previously observed between LW6 and LW9, where fracturing was first observed during the mining of LW9.
Donalds Castle Creek	Localised additional **ponding** or **flooding** developing in the locations of existing pools, steps or cascades due to vertical subsidence or tilt.	No reported impacts due to the mining-induced vertical subsidence or tilt.
	Fracturing of the bedrock directly above the longwall, however, the majority of this section of the creek has soil accumulations (i.e. only isolated outcropping of bedrock above the longwall). Also, possible for some minor **fracturing** of the bedrock outside and within 400 m of the longwalls due to strain.	No reported impacts.
	Surface water flow diversions could occur directly above the longwall due to fracturing of the bedrock	No reported impacts.
Drainage lines	Localised additional **ponding**, **flooding** or **scouring** along sections of the drainage lines located directly above the longwall.	No reported impacts.
	Buckling and **fracturing** of the bedrock along the drainage lines above or within 400 m of the longwalls.	Rock fracturing identified at 3 sites along WC15 due to the mining of LW15. Fracturing previously identified at 16 other sites along WC15 due to the mining of LW13 and LW14. Rock fracturing identified at 3 sites along LA4A; however, these are likely due to the mining of LW14. Refer to the IMC landscape report for further details.
	Surface water flow diversions into the dilated strata beneath the drainage lines which are directly mined beneath.	No new surface water diversions identified due to the mining of LW15. However, fracturing along WC15 and LA4A are located along the main channels and surface water diversions are possible during higher surface water flow conditions. Refer to the IMC landscape report for further details.
	Water quality – refer to the accompanying water quality report. **Terrestrial ecology** – refer to the accompanying terrestrial ecology report. **Aquatic ecology** – refer to the accompanying aquatic ecology report.	
Cliffs	Fracturing resulting in isolated **rockfalls** for the cliffs that are located within and just outside the mining area. Large-scale cliff instabilities are not expected.	Fracturing observed in the minor cliff located along the ridgeline above the eastern ends of LW14 and LW15, with widths up to 80 mm. Minor rock falls observed. Refer to the IMC landscape report for further details.

Natural feature	MSEC assessed impacts	Reported impacts
Rock outcrops	Fracturing of bedrock which could result in **rockfalls** along the exposed rockfaces. Fracture widths up to approximately 300 mm previously observed at the Mine.	Fracturing and minor rock falls in rock outcrops located in the valley of LA3 to the west of Swamp 23. Refer to the IMC landscape report for further details
Steep slopes	**Soil slippage** resulting in tension cracks and compression ridges. Soil cracks between approximately 100 mm and 400 mm previously observed at the Mine.	Soil cracking observed on or near the fire trails, seismic tracks and railway corridor. Crack widths vary between 2 mm and 60 mm. Refer to the IMC landscape report for further details.
Swamps	**Fracturing** of the underlying strata which could result in the **diversion of surface water**.	Groundwater levels lower than baseline and recession rates greater than baseline for Swamps 14 and 23. Soil moisture levels lower than baseline in Swamp 14. Refer to the IMC landscape report for further details.
Aboriginal heritage sites	Impacts on overhang sites include fracturing of sandstone, rock falls, or water seepage through joints which may affect artwork.	Refer to the accompanying cultural heritage report

The extraction of LW6 to LW15 has resulted in one Type 3 impact along Wongawilli Creek. A Type 3 impact is defined as *fracturing in a rockbar or upstream pool resulting in reduction in standing water level based on current rainfall and surface water flow*. The total length of Wongawilli Creek located within a distance of 400 m of the as-extracted longwalls is 2 km. The rate of Type 3 impacts along the creek due the mining of LW6 to LW15, therefore, is considered to be very low.

The longwalls at Dendrobium Mine were setback from Wongawilli Creek so that the predicted closure is less than 200 mm. It was assessed that the likelihood of significant fracturing resulting in surface water flow diversions along Wongawilli Creek would be very low, i.e. affecting less than 10 % of the pools and channels. It is considered that the observed rate of impact (i.e. one Type 3 impact along the 2 km length of Wongawilli Creek) is similar to the MSEC assessments provided in Reports Nos. MSEC459, MSEC792 and MSEC865.

Rock fracturing was observed along WC15 and LA4A at distances ranging between 30 m and 140 m from the longwall mining area. It was assessed that rock fracturing could occur along the streams up to approximately 400 m from the mining area.

No new surface water diversions were identified due to the mining of LW15. However, fracturing along WC15 and LA4A are located along the main channels and surface water diversions are possible during higher flow conditions. There are seven sites with identified or possible Type 3 impacts located along WC15 due to the mining of LW13 to LW15, being Rockbars 0/1, Rockbar 5, Rockbar 18, Rockbar 21, Rockbar 25, Rockbar 26 and Pool 30/Channel 30. There are also two sites with identified or possible Type 3 impacts located along LA4A and LA4B which were previously observed due to the mining of LW12 and LW13.

To date, there is a total of nine Type 3 impact sites along the unnamed streams that are located outside but within 400 m of the completed LW9 to LW15 in Area 3B. However, there are also 73 other rockbars that are located outside and within 400 m of the longwall mining area that did not experienced Type 3 impacts.

The observed impact rate of rockbars located along the unnamed streams located outside and within 400 m of LW9 to LW15 therefore is 11 %. While the assessed rate of impact was not provided in Reports Nos. MSEC459, MSEC792 or MSEC865, the proportion of affected sites is considered low when compared with the affected sites located directly above the longwall mining area.

It is considered, therefore, that the observed impacts on the natural features due to the extraction of LW15 are consistent with the MSEC assessments provided in Reports Nos. MSEC459, MSEC792 and MSEC865. Further assessments of natural features have been provided by other specialist consultants on the project, which are described in the relevant reports accompanying the *End of Panel* report.

3.3. Built features

The built features near LW15 are shown in Drawing No. MSEC1101-03, in Appendix A, and include:

- Fire trails and four-wheel drive tracks;
- Disused Maldon Dombarton Railway Corridor;
- Avon Dam; and
- Survey control marks.

Cordeaux Dam Wall is located more than 5 km north of LW15, at its closest point. The Upper Cordeaux No. 2 Dam Wall is located more than 6 km south-east of LW15, at its closest point. It is unlikely that these dam walls would experience measurable far-field horizontal movements resulting from the extraction of LW15 and, therefore, they have not been assessed further.

The MSEC assessed impacts for the built features resulting from the extraction of Dendrobium LW9 to LW18 are provided in Report No. MSEC459, which supported the SMP Application. These assessments were reviewed and updated based on the re-calibrated subsidence model and are provided in Reports Nos. MSEC792 and MSEC865.

Comparisons between the MSEC assessments and the reported impacts for the built features listed above, resulting from the extraction of LW15, are provided in Table 3.3. The reported impacts are based on those recorded by IMC Environmental Field Team that are described in the accompanying landscape report.

Table 3.3 Assessed and reported impacts for the built features due to LW15

Built feature	MSEC assessed impacts	Reported impacts
Fire trails and four-wheel drive tracks	Cracking of unsealed road surfaces.	Soil / surface cracking observed on or near the fire trails, seismic tracks and railway corridor, with widths ranging between approximately 2 mm and 80 mm. Refer to the IMC landscape report for further details.
Disused Maldon-Dombarton Railway	Possible fracturing of rock cuttings, spalling, and/or mobilisation of rock joints.	Surface cracking and rock fracturing above LW15 along the alignment of the railway corridor.
Avon Dam	Adverse impacts not anticipated.	No reported impacts on the dam walls. Refer to associated groundwater report for further details on impacts to the stored water.
Survey control marks	Vertical and horizontal movements which could require re-establishment.	No reported damage to the survey control marks. The marks to be re-established after completion of mining, as required.

It has been considered that the observed impacts on the surface infrastructure, resulting from the extraction of LW15, are similar to or less than the MSEC assessments provided in Reports Nos. MSEC459, MSEC792 and MSEC865.

4.0 SUMMARY

The mine subsidence movements due to the extraction of LW15 were measured using the Wongawilli Creek closure lines, Avon Dam closure lines, Area 3B and Avon Dam 3D monitoring points, WC15 and WC21 cross lines, swamp cross lines and airborne laser scans of the area.

The measured ground movements after the extraction of LW15 were similar to or less than the predicted values based on the re-calibrated subsidence model outlined in Reports Nos. MSEC792 and MSEC865. It is considered, therefore, that the ground movements measured due to the extraction of LW15 are consistent with the predictions provided in Reports Nos. MSEC792 and MSEC865.

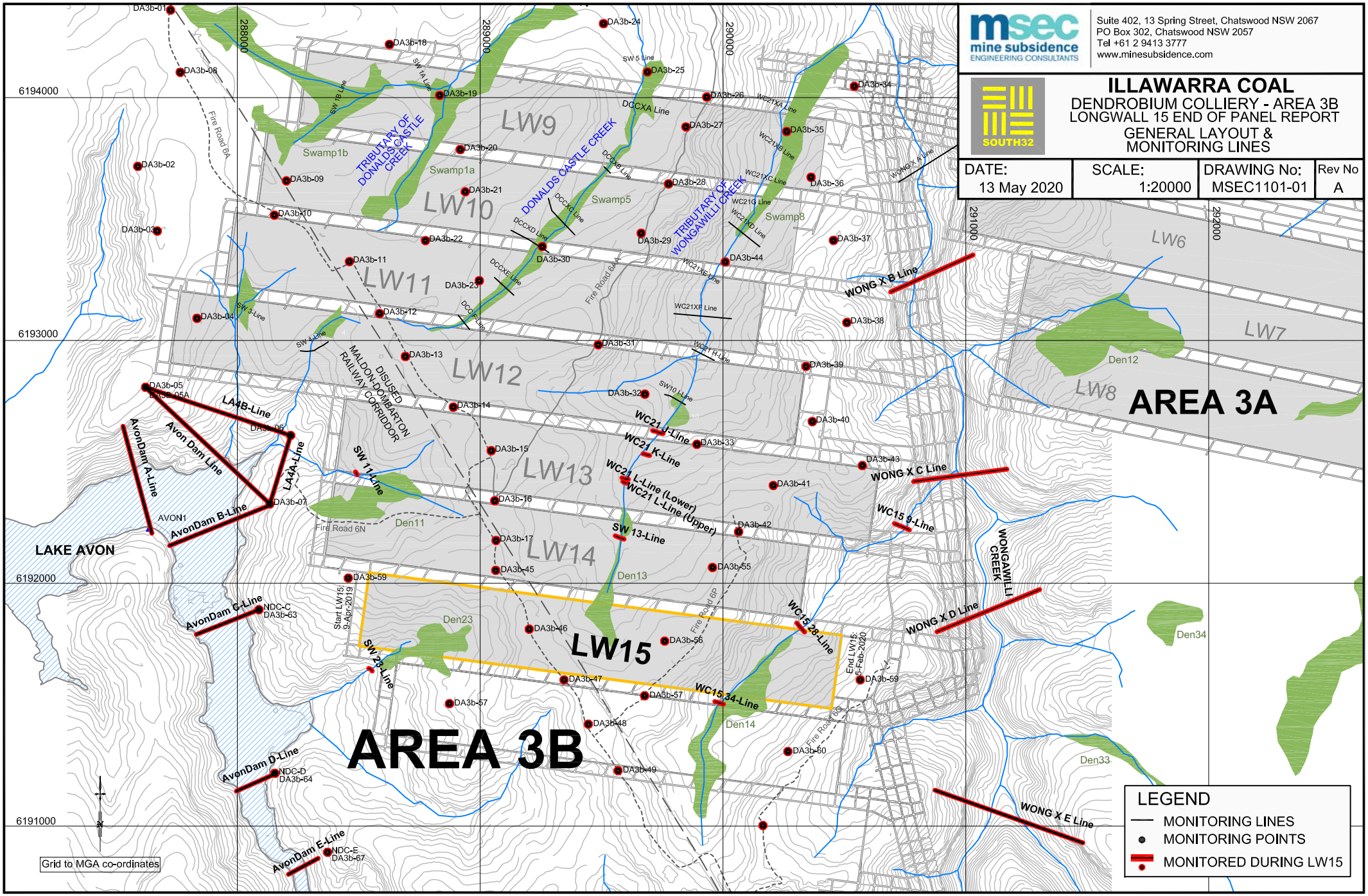
Soil cracking and rock fracturing were observed directly above LW15, the previously extracted LW14 and along the streams at distances up to 130 m outside of the mining area. The crack and fracture widths vary between approximately 2 mm and 80 mm. It was assessed that soil and fracture widths between approximately 100 mm and 400 mm could occur directly above the extracted longwalls and that more isolated surface impacts could occur up to 400 m outside of the longwalls.

No new surface water diversions via fracturing in the streams were identified due to the mining of LW15. However, fracturing along WC15 and LA4A are located along the main channels and surface water diversions are possible during higher flow conditions. To date, there is a total of nine Type 3 impact sites along the unnamed streams that are located outside but within 400 m of the completed LW9 to LW15 in Area 3B. This represents an impact rate of approximately 11 % of the rockbars located outside and within 400 m of the longwall mining area. The proportion of affected sites is considered low when compared with the affected sites located directly above the longwall mining area.

It is considered, therefore, that the observed surface impacts on the natural and built features, resulting from the extraction of LW15, are consistent with the MSEC assessments provided in Reports Nos. MSEC792 and MSEC865. Further assessments for the natural features have been provided by the specialist consultants on the project and the findings in this report should be read in conjunction with the findings provided in the accompanying specialist reports.

APPENDIX A. DRAWINGS

I:\Projects\Dendrobium\Area 3\MSEC1101 - Area 3B - Longwall 15 End of Panel Report\AcadData\MSEC1101-01 General Layout.dwg



msec mine subsidence ENGINEERING CONSULTANTS
Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

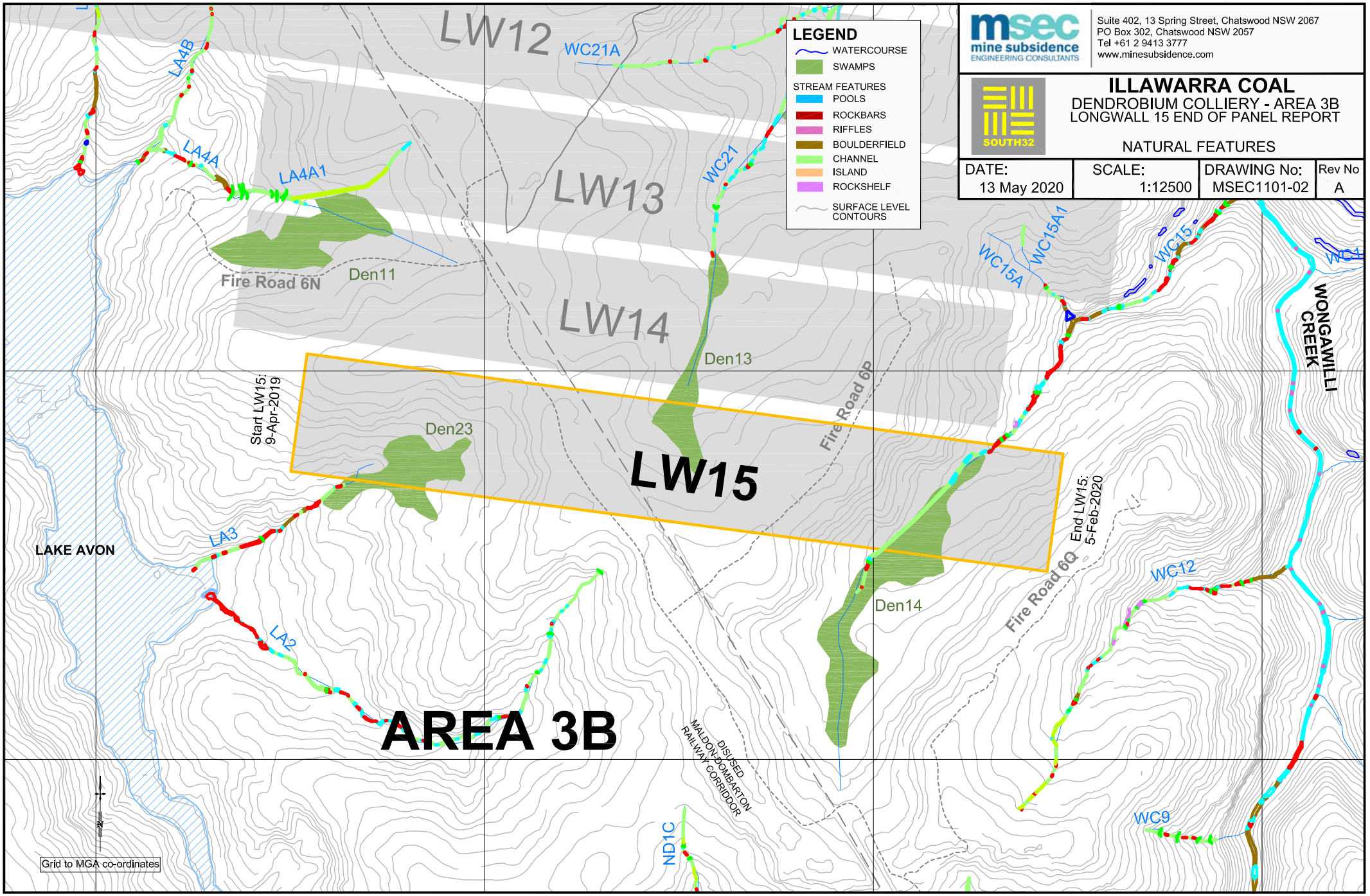
SOUTH32

ILLAWARRA COAL

DENDROBIUM COLLIERY - AREA 3B
LONGWALL 15 END OF PANEL REPORT
GENERAL LAYOUT & MONITORING LINES

DATE:	SCALE:	DRAWING No:	Rev No
13 May 2020	1:20000	MSEC1101-01	A

I:\Projects\Dendrobium\Area 3\MSEC1101 - Area 3B - Longwall 15 End of Panel Report\AcadData\MSEC1101-02 Natural Features.dwg



msec mine subsidence ENGINEERING CONSULTANTS
Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

SOUTH32

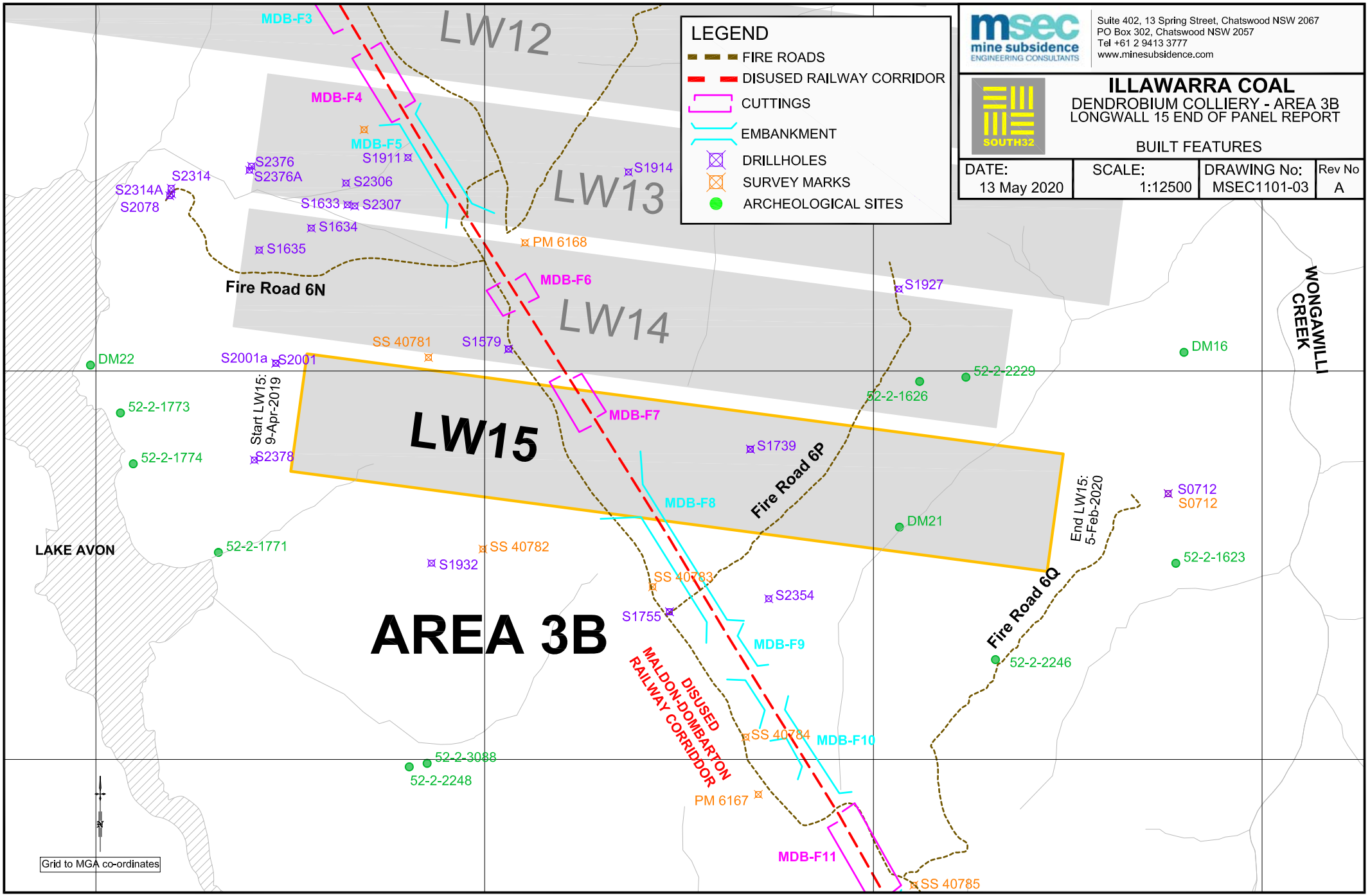
ILLAWARRA COAL

DENDROBIUM COLLIERY - AREA 3B
LONGWALL 15 END OF PANEL REPORT

NATURAL FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
13 May 2020	1:12500	MSEC1101-02	A

I:\Projects\Dendrobium\Area 3\MSEC1101 - Area 3B - Longwall 15 End of Panel Report\AcadData\MSEC1101-03 Built Features.dwg



msec mine subsidence ENGINEERING CONSULTANTS
Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

SOUTH32

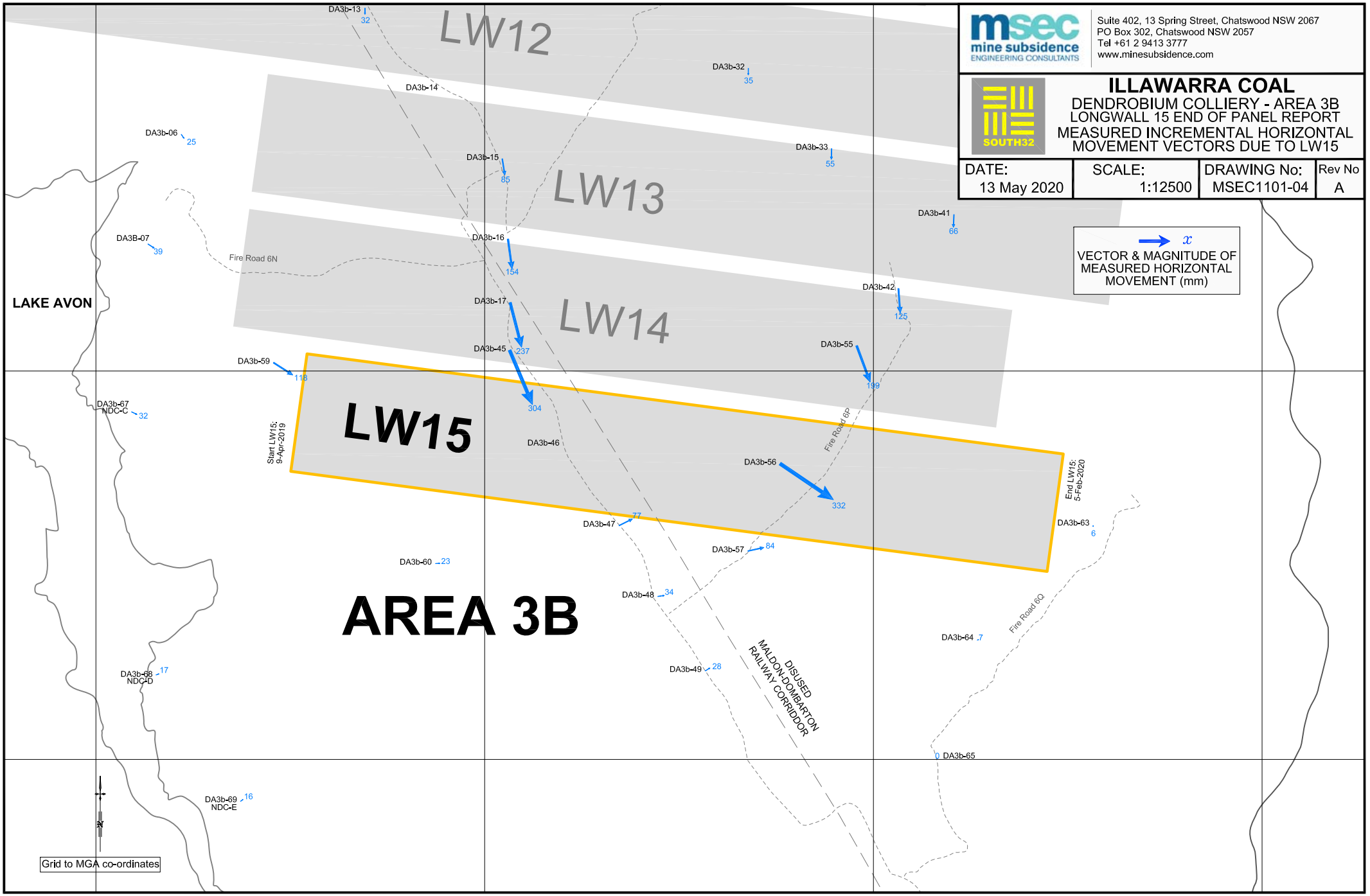
ILLAWARRA COAL

DENDROBIUM COLLIERY - AREA 3B
LONGWALL 15 END OF PANEL REPORT

BUILT FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
13 May 2020	1:12500	MSEC1101-03	A

I:\Projects\Dendrobium\Area 3\MSEC1101 - Area 3B - Longwall 15 End of Panel Report\AcadData\MSEC1101-04 Observed Hzl Vectors.dwg



msec mine subsidence ENGINEERING CONSULTANTS
Suite 402, 13 Spring Street, Chatswood NSW 2067
PO Box 302, Chatswood NSW 2057
Tel +61 2 9413 3777
www.minesubsidence.com

SOUTH32

ILLAWARRA COAL

DENDROBIUM COLLIERY - AREA 3B
LONGWALL 15 END OF PANEL REPORT
MEASURED INCREMENTAL HORIZONTAL MOVEMENT VECTORS DUE TO LW15

DATE:	SCALE:	DRAWING No:	Rev No
13 May 2020	1:12500	MSEC1101-04	A